Rev. Écol. Biol. Sol, 1986, **23** (3) : 271-286.

Effects of fertilization and manipulation of pH on mite (Acari) populations of coniferous forest soil

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Synopsis: Influence of urea- and ash-fertilization upon mite communities of coniferous forest soil was studied in field and laboratory. Ash-treatment was also controlled by manipulating the pH to the same level with $Ca(OH)_2$, and urea-treatment with NH_4NO_3, in order to separate the impact of pH from that of nutrients. Soil acidity was considered to be an essential factor to explain the changes observed, but nitrogen also played role independently of pH.

Keywords: Fertilization - pH - Forest soil - Acari - Oribatida - Mesostigmata.

INTRODUCTION

Mites (Acari) are next to nematodes the most abundant group of metazoan animals in forest soil. Acid raw humus prevailing in northern coniferous forests is an especially favourable habitat for oribatid (cryptostigmatid) mites, their numbers often rising up to several hundreds of thousands per square metre. In dry forest types where large decomposers, especially earthworms, are sparse, the contribution of mites to the total biomass of soil animals is also essential (PERSSON *et al.*, 1980), and not unimportant even at more productive stands (review by PETERSEN & LUXTON, 1982).

Fertilization has during the last two decades become a common practice to improve the productivity of coniferous forests. Its influence on the living

Reçu le 10-6-86.
Accepté le 10-8-86.

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soil community is poorly understood. Most investigations dealing with the response of microarthropods to mineral fertilizers have been made at level of major taxonomic units (review by MARSHALL, 1977). Only LOHM *et al.* (1977) and BEHAN *et al.* (1978) have studied effects of nitrogen fertilizers on microarthropods of forest soil at the level of different species.

There are various mineral fertilizers, which differ in their acidity, or after application may result in different reactions in the soil pH. Recently HÅGVAR & ABRAHAMSEN (1980); HÅGVAR & AMUNDSEN (1981); HÅGVAR & KJÖNDAL (1981 a, b); and HÅGVAR (1984 a) have demonstrated clear relationships between soil acidity and-several mite species. Because there are connections between forest fertilization and problems of acid precipitation, it is of interest to know the role of acidity in the effects of fertilizers.

I. — MATERIAL AND METHODS

Because the study sites and experimental design were described in detail by HUHTA (1984), only the most essential facts are given here. (Note that the present study includes only part of the experiments described therein.)

Field experiment 1 was performed in a *Calluna-type* pine stand in southern Finland. The study plot proper, 10 × 10 m, was fertilized with ashes (7 000 kg.ha^{-1}), two similar untreated plots serving as controls. Samples were taken monthly during the second growing period (1980) after treatment. Each sample consisted of ten 25 cm^2 soil cores taken from the fertilized plot, and 5 + 5 from the control plots. Samples were divided into two layers, 0 - 3 and 3 - 6 cm, which were treated separately.

Field experiment 2 was established in a young pine stand at Ruotsinkylä, 25 km N of Helsinki. Ten 4 × 4 plots were divided into four quadrats, each receiving one of the four treatments: ashes, 6 700 kg ha^{-1} added with superphosphate, 44 kg P ha^{-1} (symbol A + P used later); lime, $Ca(OH)_2$, 4 000 kg ha^{-1} (symbol Ca); urea, 460 kg N ha^{-1} (U) and control (C). The fertilizers were spread in two dosages on 13 May and 1 June 1981. The samples included one soil core from each subplot. The first samples (area 25 cm^2 per unit) were taken in Sept. 1981, and the following ones (area 10 cm^2 each) in May and July 1982, and May 1983.

Laboratory experiments 1 and 2 were designed to separate the effects of pH from those of nutrients. Six intact blocks of soil, including vegetation and the topmost 1 cm of mineral soil, were placed in plastic boxes measuring 40 × 60 cm, depth 11 cm. Organic soil was taken from the same site, sieved with a 10 mm mesh, mixed well and divided for different treatments. The chemicals to be tested were weighed and mixed thoroughly with this soil. Equal portions of each treatment were then placed into small mesh baskets (mesh 1.5 mm, depth 8 cm, diameter 4 cm), which were inserted into holes of corresponding size bored in the soil blocks in the boxes. These were then covered with perforated plastic, kept moist by watering and incubated at fluctuating temperature (day + 20° C, night + 15° C). Both experiments were interrupted by a simulated winter: the temperature was gradually lowered close to freezing point for ca. 2 months. The treatments were:

Experiment 1: Birch ashes, 9.7 g, added with superphosphate, 1.4 g . kg^{-1} (f.w.) of soil, equivalent to 1 750 kg ashes and 22 kg P . ha^{-1}; slaked lime, $Ca(OH)_2$, 9.7 g . kg^{-1}; control without fertilizers.

Experiment 2: Urea, 2.6 g . kg^{-1} (f.w.) of soil; ammonium nitrate, 3.4 g . kg^{-1}, both equivalent to 150 kg N . ha^{-1}; control without addition of N.

At selected intervals, 6 random replicates (one from each box) of each treatment were removed for extraction.

Animals were extracted from the samples using the « high gradient » extractor, with the « medium » heating regime recommended by LEINAAS (1978) for raw humus. Mesostigmata were picked from whole samples and identified with microscope, mainly using the key of KARG (1971), but after checking from most recent revisions of genera or families. All adult oribatids were identified with a binocular microscope using mainly the key of GHILAROV (1975). Identification was done from whole laboratory samples and field samples of 10 cm^2, while samples of 25 cm^2 were at first divided in two with a sample splitter.

Biomass were estimated using the data of LUXTON (1975) for adult oribatids, those of PERSSON & LOHM (1977) and HUHTA *et al.* (1979) for Mesostigmata, and regressions of HUHTA & KOSKENNIEMI (1975) for Prostigmata, Astigmata and juvenile Oribatida.

Difference between treatments and their respective controls were tested with ANOVA after logarithmic transformation log $(X + 1)$. In the laboratory experiments and Field Exp. 1 all samples were included in the same test. In Field Exp. 2, samples 3 and 4 were included in the « main » test, while the first sample was tested separately, and the second sample was omitted from the statistical treatment. This was done because preliminary examination revealed that the effects of treatments had not yet appeared by the first sampling, or were even the opposite to the later samples. The second sample represented an intermediary stage before longterm effects. Tests on the field data were performed separately for each species and horizon 0-3 and 0-6 cm, and for total numbers also for the horizon 3-6 cm.

In Lab. Exp. 2 the first and last samples were omitted from the analyses, because animals at first suffered from mechanical mixing of the soil, and finally, after long incubation, the experiment was considered senescent.

II. — RESULTS

A) Field experiments.

1. *Experiment 1 with ashes.*

At the study site Tammela sampling was started one year after fertilization with ashes, and continued monthly until September.

Ash-treatment appeared to exert strong influence on mite populations, especially on Oribatida. The densities of as many as 14 taxa were significantly different from those in untreated soil. With the exception of *Ceratozetes gracilis* all significant reactions were negative. The results are summarized in Table I, where all species occurring in densities exceeding 5 000 specimens per square metre are listed. In addition, *Carabodes marginatus* (Mich.), *Scheloribrates latipes* (Koch) and *Steganacarus carinatus* (Koch) showed significant decrease.

Fertilization had considerably changed the vertical distribution of oribatids. Virtually all significant differences between treated soil and control were observed in the surface layer (0 - 3 cm), whereas in the lower horizon there were either no changes or even a non-significant tendency to increase. In Table I only summed figures from both layers are presented, but because the reactions of most species were consistent, the shift in vertical distribution can be clearly seen in total numbers (Fig. 1).

Among Mesostigmata, only few species had reacted significantly to the treatment: *Eviphis ostrinus* (Koch) occurred in higher density, while

TAB. I

Monthly mean numbers (x 10^{-2} m^{-2} ; sums from both layers, 0-6 cm) of the most abundant mite species in Field Exp. 1 (Tammela 1980). Significant differences from the control are indicated in column « P » (* = $P < 0.05$, ** = $P < 0.01$; in parentheses if significant in 0-3 cm only.) Note that the seasonal variation has been removed by ANOVA and neglected here. n.d. = not determined

	May	June	July	Aug.	Sept.	X	P
Brachycthoniidae *spp.* :							
Control	n.d.	522	314	403	566	451	
Ash	n.d.	169	383	198	548	325	**
Nanhermannia sellnicki Forsslund :							
Control	170	55	41	74	193	109	
Ash	0	0	0	0	0	0	**
Carabodes subarcticus Trägårdh :							
Control	99	34	25	30	40	50	*
Ash	18	12	6	6	54	18	(**)
Tectocepheus velatus Mich. :							
Control	437	272	201	324	479	347	
Ash	116	105	146	106	515	187	**
Suctobelbidae *spp.* :							
Control	205	164	153	158	266	190	
Ash	97	111	142	78	308	142	**
Oppiella nova (Oudemans) :							
Control	180	217	146	189	224	192	
Ash	157	217	117	148	321	187	
Oppia subpectinata Oudemans :							
Control	77	41	44	26	112	60	
Ash	36	29	22	25	51	32	**
Autogneta trägårdhi Forsslund :							
Control	92	61	49	101	35	69	
Ash	13	4	7	4	15	9	**
Scheloribates confundatus Sellnick :							
Control	66	33	71	42	91	60	
Ash	44	22	22	28	70	36	(**)
Ceratozetes gracilis (Michael) :							
Control	27	25	15	30	22	24	
Ash	37	30	58	24	100	48	**
Chamobates schützi (Oudemans) :							
Control	82	28	35	31	70	50	
Ash	34	31	28	27	54	34	*
Veigaia nemorensis (C. L. Koch) :							
Control	22	12	25	41	30	27	
Ash	10	4	6	16	40	15	**
Parazercon radiatus (Berl.) :							
Control	28	59	31	50	36	40	
Ash	36	57	43	62	53	49	

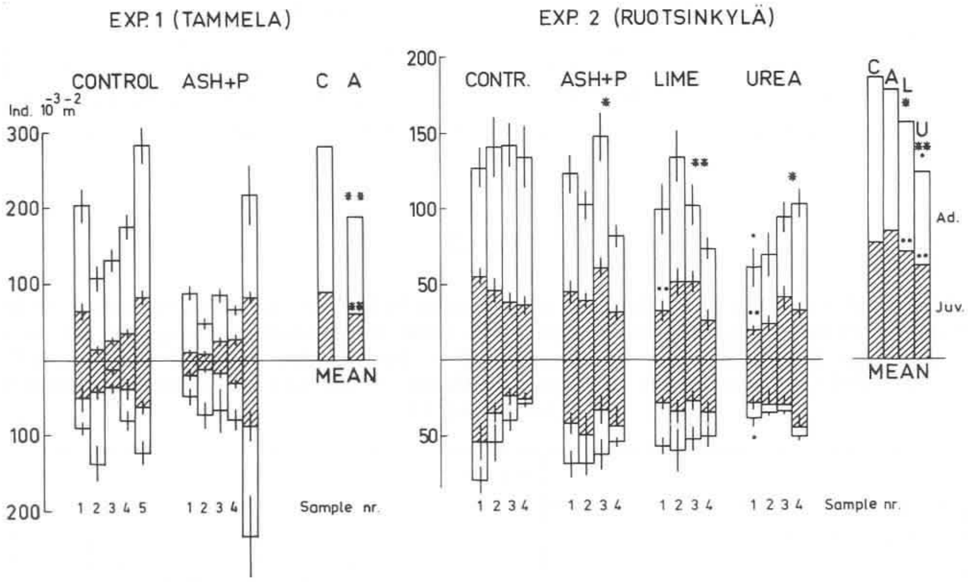

FIG. 1. — Numbers of adult (white parts of the columns) and juvenile (hatched) Oribatida ± SE in the field experiments. Layer 0-3 cm shown above the base line, layer 3-6 cm below it; in the columns « mean » sums from both layers are shown above the base line. Significant difference from the control indicated with asterisks (* = $P < 0{,}05$, ** = $P < 0{,}01$). For Exp. 2 these refer to samples 3 and 4 only, the first samples have been tested separately, and the significant differences are shown with dots correspondingly.

Prozercon kochi Selln. and *Veigaia nemorensis* had decreased. There was no shift in vertical distribution corresponding to that in oribatids. Total numbers of Mesostigmata and Prostigmata did not differ from those in the control plots. Table I shows species present in densities more than 2000/m^2. Numbers of Astigmata were low at the site studied.

Total biomass of oribatids decreased after ash-fertilizing approximately in proportion to their numbers: it was 42 % lower in the treated plot (474 mg d.w. m^{-2}) than in control soil (824 mg). All the change took place in the surface layer: at 3 - 6 cm the biomass remained unchanged. Total biomass of Mesostigmata had decreased from 146 mg m^{-2} to 101 mg in the treated plot. Biomasses of Prostigmata and Astigmata were small and did not change essentially.

2. *Experiments 2 wih ashes and Lime.*

Sampling at Ruotsinkylä was started ca. 4 months after the first application of fertilizers, and continued at longer intervals and during a longer time span than in Tammela, so that the last samples were taken 2 years after the treatments.

It came out that the effect of ashes on oribatid mites was so gradual that virtually no changes took place by the first sampling. Harmful impact of the treatment became evident later, both in decreased numbers of adults

in the surface horizon, and in clear shift of vertical distribution in favour of the 3 to 6 cm layer. An absolute increase in 3-6 cm was observed in *T. velatus, N. silvestris,* Suctobelbidae spp and Brachycthoniidae spp., and in total numbers as well. When summed figures from both horizons were tested, all significant changes recorded were negative (Fig. 1, Tab. II).

TAB. II

Mean numbers of the most abundant mite species (x 10^{-2} m^{-2} totals of 0-6 cm) in Field Exp. 2 (Ruotsinkylä). Significant differences from the control indicated in the first column for Sept. 1981, and in column « P » for samples 3 and 4. (* = $P < 0.05$, ** = $P < 0.01$; in parentheses if more significant in 0-3 cm. ° = difference between A + P and L)

	Sept. 81	May 82	July 82	May 83	X	P
Brachychthoniidae *spp.* :						
Control	98	190	158	217	165	
Ash + P	151	81	104	51	94	(**)
Lime	88	195	88	76	108	**
Urea	53	52	40	127	70	(**)
Nothrus silvestris Nicolet :						
C	32	27	26	18	26	
A + P	13	11	15	7	11	*
L	26	27	20	7	19	*
U	10	15	10	11	12	
Suctobelbidae *spp.* :						
C	310	476	409	254	360	
A + P	235	339	273	160	253	**
L	303	253	329	146	255	**
U	89**	108	167	42	100	**
Tectocepheus velatus :						
C	147	151	181	221	176	
A + P	240	94	208	64	147	(**)
L	231	235	157	136	187	(*)
U	114	106	78	168	118	
Oppiella nova :						
C	183	132	161	133	153	
A + P	221	168	270	148	201	
L	114	176	86	69	108	*°
U	111	192	217	126	164	
O. subpectinata :						
C	37	59	51	28	43	
A + P	55	55	98	14	56	
L	23	21	28	16	22	
U	43	21	23	38	31	
Ceratozetes gracilis :						
C	14	23	87	21	38	
A + P	22	6	43	30	25	

TAB. II *(cont.)*

	Sept. 81	May 82	July 82	May 83	X	P
L.	47	44	46	29	41	
U.	8	8	6	33	15	
Chamobates schützi :						
C.	30	19	30	38	30	
A + P.	41	14	27	39	30	
L.	20	9	27	38	25	
U.	16	8	45	58	33	
Veigaia nemorensis :						
C.	52	24	22	9	27	
A + P.	55	11	32	7	26	
L.	33	16	23	7	20	
U.	21	2	13	1	9	••
Parazercon radiatus :						
C.	60	14	42	37	38	
A + P.	56	26	59	21	40	
L.	36	9	39	13	24	oo
U.	26	34	19	24	26	

Liming (calcium hydroxide) affected the oribatid mites about equally strongly as did ash-treatment. However, it had a more harmful short-time effect on immatures, which were significantly less abundant in the first samples (the same tendency can be seen after ash-fertilization). Lime-treated and ash-treated plots differed from ach other significantly in one case only (*Oppiella nova, $P < 0.05$*). Due to its weak response to ashes (see also Exp. 1), its share in the total numbers of adult oribatids remained higher (22 %) than in either lime-treatment (13 %) or control (14 %).

Trachytes aegrota (C. L. Koch) was the only species of Mesostigmata that showed significant response (increase; $P < 0.05$) to ashes, and *Hypoaspis aculeifer* (Can.) the only one to react after liming (increase, $P < 0.01$), but both were sparse in the control soil and only reached densities of about 1 000/m^2 (mean) after the treatments. On the contrary, prostigmatid mites reacted very strongly. In both treatments and both soil layers their numbers had decreased by the first sampling, but later their populations recovered so that the ash-fertilized plots harboured higher numbers than did the control soil. Recovery was weaker in the limed plots; difference from the control remained insignificant, but that from ash-treatment was not significant either (Fig. 2).

3. *Experiment 2 with urea.*

The response of oribatids on urea treatment was very profound and became evident already by the first autumn as a significant drop in numbers (more than 50 %, both adults and juveniles). The early effect was greatly due to abrupt decrease of Suctobelbidae, but other species were also involved. Later the populations started to recover: by July 1982 the total density of

immatures reached the control level, while the numbers of adults were 24 % below control still in May 1983 (Fig. 1). Suctobelbidae spp. and Brachycthoniidae spp. were still suffering from the fertilization after two years (Tab. II).

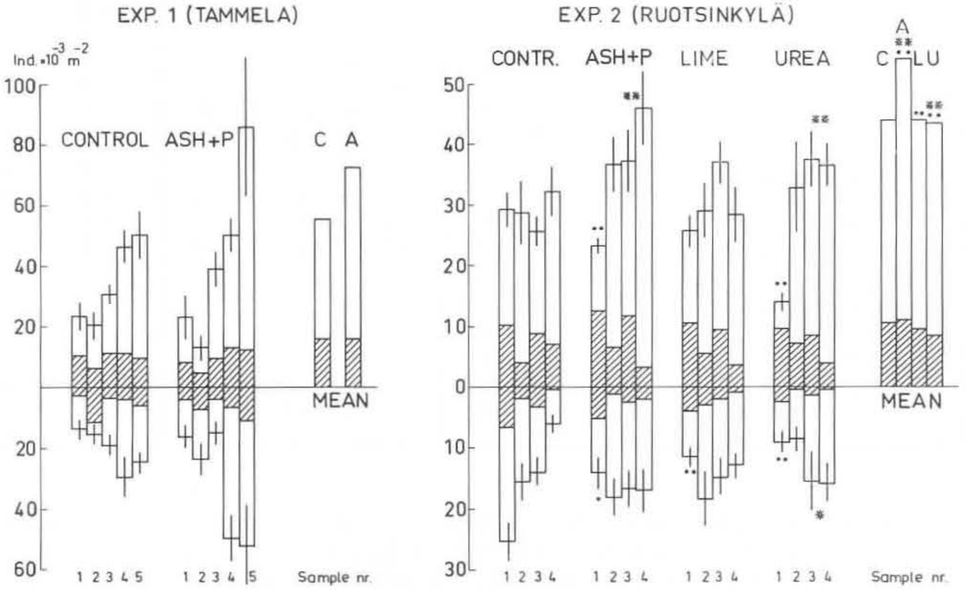

FIG. 2. — Numbers of Prostigmata (white parts of the columns) and Mesostigmata (hatched) ± SE in the field experiments. Other explanations as in Fig. 1.

Two species of Mesostigmata reacted significantly to urea. These were *Veigaia nemorensis* which decreased to one third of the control numbers (mean), and *Dinychella asperata* Berl., which appeared in the treated plots in a considerable density (1 900 m^{-2}) in Sept. 1981, but disappeared by May 1983. Prostigmatids responded to urea in the same way as they did to ashes but the short-time effect was even more destructive: total density decreased by 77 % (Fig. 2). The recovery was correspondingly more rapid, and so the control level was reached by the following summer.

The changes in the total biomasses of different mite groups were roughly similar to those in numbers.

B) **Laboratory experiments.**

1. *Experiment 1 with ashes and lime.*

There were highly significant differences between treated (both ash and lime) and untreated soil both in total numbers of Oribatida and in populations of several species (Fig. 3, Tab. III). Mean numbers of adult oribatids remained about two thirds lower than those in the control. *T. velatus*,

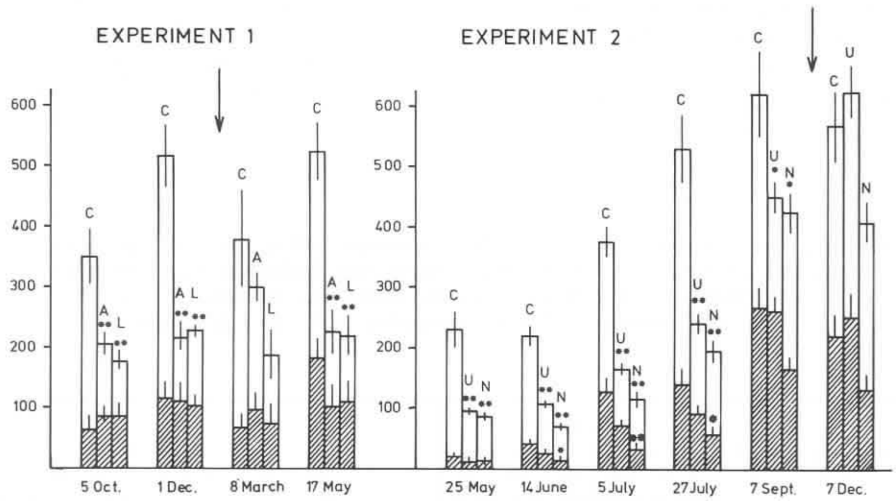

FIG. 3. — Numbers of adult (white parts of columns) and juvenile (hatched) Oribatida per sample unit ± SE in the laboratory experiments. Significant differences from the respective controls are indicated above the columns for adults, and above the hatched parts for juveniles. The vertical arrows indicate between which samples artificial winter was arranged. C = control, A = ash, L = lime, U = urea, N = NH_4NO_3.

N. silvestris, Suctobelbidae spp. and Brachycthoniidae spp. reacted most strongly. *O. subpectinata* was initially more abundant in the treated soil, but later the differences disappeared. *C. gracilis* did not react significantly, which is consistent with Field Exp. 2.

In spite of the marked decrease of adult oribatids, immatures showed no response to the treatments. The same holds true for Prostigmata, while Astigmata and Mesostigmata suffered. Among mesostigmatids *Parazercon radiatus*, *Pergamasus parrunciger* and *Veigaia nemorensis* decreased significantly.

Statistical analyses did not reveal any significant differences between ash-treated and lime-treated soil.

2. *Experiment 2 with nitrogen fertilizers.*

The impacts of both nitrogen treatments on oribatids were rather similar and of the same magnitude. Numbers of both adults and immatures were significantly lower in treated soil. In the average, immatures suffered less and recovered earlier to the control level, which was reached by adults only in the last sample from the urea treatment (Fig. 3). Several species and taxa reacted significantly, and all these reactions were negative (Tab. III).

Although the changes caused by NH_4NO_3 were of the same direction as those by urea, there were some significant differences between these. Juvenile oribatids did not recover to the control level after NH_4NO_3, and *Ceratozetes gracilis* did not react to this treatment.

Total numbers of Mesostigmata, Prostigmata and Astigmata showed only slight or no response to urea, while the impact of NH_4NO_3 was clearly negative. *P. radiatus* was the only mesostigmatid species that reacted significantly to urea, while *P. parrunciger* and *V. nemorensis* contributed in the decrease after ammonium nitrate treatment.

TAB. III

Numbers of the most abundant mite species per sample unit in the laboratory experiments. Significant differences from the control are indicated with asterisks (* = $P < 0.05$, ** = $P < 0.01$). ° = sign. difference between U and AN, • = sign sample/treatment interaction. n.d. = not determined

Experiment 1 :

Treatment Age, week	Control					Ash + P					Lime				
	8	16	30	38	$\bar{X}$	8	16	30	38	$\bar{X}$	8	16	30	38	$\bar{X}$
Brachychthoniidae *spp.*	56	100	20	18	49	21	14	11	4	12**	14	16	6	3	10**
Nothrus silvestris	8	9	7	8	8	2	0	2	2	1**	2	1	0	3	2**•
Suctobelbidae *spp.*	92	185	219	251	187	16	55	127	69	67**	14	58	79	62	53**
Tectocepheus velatus	39	26	17	14	24	10	8	11	3	8**	8	8	2	4	5**
Oppiella nova	34	40	19	8	25	14	4	17	5	10*	14	8	5	2	8**
Oppia subpectinata	10	15	13	16	14	24	10	17	7	15	20	12	8	7	12
Ceratozetes gracilis	21	18	6	7	13	7	3	8	7	7	3	10	5	11	7
Parazercon radiatus	21	47	18	17	26	7	16	8	7	9**	n.d.	31	10	8	16
Pergamasus parrunciger	3	4	12	9	7	2	4	4	5	4**	n.d.	3	10	3	5*
Veigaia nemorensis	11	32	8	5	14	10	18	3	3	8*	n.d.	29	2	2	11*
Total Mesostigmata	42	94	47	36	54	28	52	26	19	31**	n.d.	73	34	17	42**
Total Prostigmata	90	48	50	52	60	113	74	74	57	80	99	108	53	63	81

Experiment 2 :

Treatment Age, weeks	Control					Urea					AN				
	3	6	9	15	$\bar{X}$	3	6	9	15	$\bar{X}$	3	6	9	15	$\bar{X}$
Brachychthoniidae *spp.*	24	39	54	41	40	12	13	19	25	17**	4	6	13	34	14**
Tryphochthoniidae *spp.*	6	18	53	16	23	3	9	15	6	8**	2	5	8	6	5**
Nothrus silvestris	13	19	10	13	14	8	11	6	10	9	4	5	7	10	7**°
Suctobelbidae *spp.*	46	75	160	172	113	15	22	46	122	51**	3	7	42	130	46**•
Tectocepheus velatus	48	37	42	22	37	15	16	15	18	16**	9	19	21	28	19**
Oppiella nova	9	8	30	28	19	5	2	17	10	9**	8	4	22	15	12*
Oppia subpectinata	17	13	27	18	19	10	7	17	10	11*	6	4	7	20	9**
Ceratozetes gracilis	19	13	9	11	13	8	7	7	6	7**	18	26	18	12	19°°
Parazercon radiatus	1	5	7	n.d.	4	1	1	1	n.d.	1**	0	0	2	n.d.	1**
Pergamasus parrunciger	7	6	7	n.d.	7	8	7	5	n.d.	7	3	4	3	n.d.	3**°
Veigaia nemorensis	4	8	11	n.d.	8	5	6	6	n.d.	6	2	5	10	n.d.	5*
Total Mesostigmata	21	36	48	n.d.	35	28	31	22	n.d.	27	8	17	23	n.d.	16**°°
Total Prostigmata	33	79	100	96	77	25	44	90	85	61*	12	19	44	90	41**°°•

III. — DISCUSSION

A) Effects of nitrogen fertilizers.

There are somewhat contradictory reports about the influence of nitrogen fertilizers on soil mites in coniferous forests. HUHTA *et al.* (1967) observed a slight increase of oribatids and other mites, which was mainly evident in the third year after application of NPK-fertilizer. MARSHALL (1974) did not discover any significant changes after urea-treatment (224 or 448 kg N ha^{-1}), although there seemed to be a slight temporary decrease. Also BEHAN *et al.* (1978) reported an initial decrease in oribatid populations after application of urea in a black spruce forest (220 to 880 kg N ha^{-1}), whereby movements into deeper soil horizons and decrease of the relative proportion of oribatids to total microarthropods was observed. In our field experiment there was also some change in the vertical distribution of juvenile oribatids, but not in that of adults, nor in other mite groups and Collembola (VILKAMAA & HUHTA, 1986). WEETMAN *et al.* (1972) reported an increase of total mite density (unidentified) after urea treatment.

LOHM *et al.* (1977) made experiments in Scots pine stands with different dosages of nitrogen, given either as urea or ammonium nitrate. 150 kg N ha^{-1} did not result in any response in the populations, but after increasing the amount of N to 480 kg ha^{-1} (three annual applications of NH_4NO_3) significant decline was observed in some species, especially Collembola. Unpublished data of SULANDER and HUHTA also indicate that nitrogen fertilizers spread in amounts used in practical forestry (150 or 200 kg N ha^{-1}) do not alter the microarthropod community. In the present study, a double dosage (460 kg), given in two applications at a short interval, was clearly enough to result in significant changes in the populations. It also caused death of mosses, which probably offered nutrition for some detritus feeders during the decomposition. An indication of this is the appearance of *Dicychella asperata*, a predatory mite living in decaying organic matter and obviously transported phoretically by flying insects. Certain Coleoptera invaded the urea-treated plots (HUHTA *et al. in press*). Nematodes that also increased after fertilizing (HYVÖNEN & HUHTA *in press*) are probable prey of *D. asperata*. BEHAN *et al.* (1978) observed an increase of Mesostigmata after urea-fertilization, and attributed this to an increase in numbers of their prey.

The effect of urea was stronger in the laboratory experiments than in the field, in spite of essentially smaller amount of N when calculated per unit area. This is understandable, however, because in the field the fertilizer was spread on the soil surface, where it was gradually dissolved by rain, and maybe also partially volatilized as ammonia (OVERREIN, 1968). In laboratory it was mixed with soil and thus could immediately react with soil water.

The results obtained by laboratory and field experiments were in no case contradictory.

B) Role of pH.

Ash-treatment and liming had similar influences on the mite populations. In the laboratory experiment (1) there were no significant differences bet-

ween the two treatments. In the field (Exp. 2) the overall changes were also the same, with a few exceptions: one mesostigmatid *(P. radiatus)* and one oribatid species *(O. nova)* showed significant difference between ash-treatment and liming. Enchytraeid worms also responded differently to these two treatments in the same experiment (HUHTA, 1984). This can be explained by different solubility of ash and lime, which may result in different vertical gradients in pH and soil processes. Even in this case, the field and laboratory experiments did not give contradictory results for any species.

Although there were few significant changes in Mesostigmata, there seems to be an overall correlation between numbers of nematodes (HYVÖNEN & HUHTA *in press*) and small predatory species *(Trachytes* spp., *Hypoaspis aculeifer, Eviphis ostrinus, Dendrolaelaps rotundus* and *Zerconidae)* that probably have nematodes in their preferable diet (KARG, 1983). However, the decrease of *Veigaia nemorensis* feeding on Collembola did not correlate with numbers of their potential prey (VILKAMAA & HUHTA, 1986).

Several studies have revealed clear relationships between microarthropods and soil pH. HÅGVAR & AMUNDSEN (1981) showed the negative influence of liming on several mite species, and effects of artificial acidification have been dealt with by BÅÅTH *et al.* (1980), HÅGVAR & AMUNDSEN (1981) and HÅGVAR & KJÖNDAL (1981 b). Considering species in common with our material, liming has been shown to decrease numbers of *T. velatus* and *N. silvestris,* and, correspondingly, acidification increased populations of *T. velatus* and Brachycthoniidae. *Suctobelba subcornigera* also showed inverse correlation with pH; the same species may predominate in our Suctobelbidae. Moreover, *O. nova* showed a non-significant increase after acidification according to BÅÅTH *et al.* (1980), and HÅGVAR & ABRAHAMSEN (1981) consider it an « acidophile » species, although its reactions were not easy to interprete. Among Mesostigmata, our results accord with those of HÅGVAR & AMUNDSEN (1981) for *Trachytes* spp., but for *Veigaia nemorensis* there is some. contradiction.

On the basis of these observations and the similar response of populations to ashes and liming, it seems obvious that the changes in the mite community after ash-fertilization can be explained by pH rather than by addition of nutrients. Both ash and lime resulted in similar changes in the soil pH (Tab. IV).

On the other hand, the nitrogen fertilizers also caused similar changes in the mite populations as did ash or lime. Because urea results in a rapid rise of pH, it can be considered possible that even in this case the reason may not be the nitrogen added but the decrease of acidity. The laboratory experiment 2 was designed to test this hypothesis. Ammonium nitrate is acid, and when mixed with soil it caused a slight initial increase of acidity. Later the pH remained almost the same as in untreated soil, while it was at least one unit higher in the urea treatment (Tab. IV). Since the response by the oribatid community was virtually similar to both forms of nitrogen, it can be concluded that nitrogen plays role independently of pH. Toxicity of ammonium nitrate in other groups of soil animals has previously obscured the interpretation of this particular experiment (HUHTA *et al.*, 1983). However, the chemical obviously had a negative influence on the reproduction of oribatids, because the numbers of immatures remained significantly lower in comparison to the urea treatment (Fig. 3).

TAB. IV

Results of pH measurements. Each figure is a mean of several recordings. Only values of the first and last samplings are given for the laboratory experiments. For details see HUHTA (1984)

Field Exp. 1 (Tammela) :				
	Control	Ash		
0-3 cm..........	4.3	6.0		
3-6 cm..........	4.2	5.3		
Field Exp. 2 (Ruotsinkylä) :				
	Control	Ash	Lime	Urea
0-3 cm..........	4.4	7.0	7.2	5.5
0-6 cm..........	4.5	5.1	5.0	5.0
Lab. Exp. 1 :				
	Control	Ash	Lime	
	4.5...4.8	6.9...5.4	7.0...5.5	
Lab. Exp. 2 :				
	Control	Urea	NH_4NO_3	
	4.4...4.9	6.5...6.1	3.8...5.0	

Liming and ash-treatment in Field Exp. 2 also resulted in changes in vertical distribution of several species. This was most evident in samples where differences in pH between the two layers was greatest, like in May 1983 (Fig. 2, Tab. IV). The same is true for several individual species, e.g. *T. velatus*, an acidophilous surface dweller (HÅGVAR, 1984 b). In the samples of May 1983, 33 % (A + P) to 41 % (L) of individuals were found at 3 - 6 cm depth in the treated plots, while only 3 % in the control plots. HÅGVAR & AMUNDSEN (1981) also showed that liming lowers the average depth of populations.

The shift in vertical distribution may be caused either by vertical movements of animals, or by better reproduction success in the lower horizon. The latter assumption is supported by the observation that in these particular samples the majority of specimens (70 to 77 %) in the 3 to 6 cm layer were immatures, whereas it was about 50 % when the pH gradient was less steep.

Obviously the reactions in the soil fauna are not directly caused either by pH changes or fertilizers, but the interpretation of true causal relationships is not easy. HÅGVAR (1984 b) presented a detailed discussion about potential mechanisms explaining the effects of acidity on microarthropods. These mechanisms may include direct influences of pH, but more probably they are mediated through indirect effects, especially changes in the composition of microflora that forms the diet to most oribatids. However, the nutrition of oribatids seems to be rather flexible and adjustable according

to the food supply of their prevailing environment, so that causal relationships are hard to verify. It is possible that addition of nitrogen, the limiting nutrient in coniferous forest soil, gives rise to a similar chain of reactions in the soil as does the neutralizing effect by ashes or lime. This may change the balance in nutritional and reproductive conditions in favour of some species at the cost of others.

Abstract

The effects of nitrogen (urea and ammonium nitrate) fertilizers and ash-treatments upon the populations and communities of mites (Acari) in coniferous forest soil were investigated in two field experiments and two laboratory experiments. In addition to untreated soil, ash-fertilizing was also controlled with $Ca(OH)_2$, in order to separate the role of nutrients from that of acidity. The two forms of nitrogen also differed from each other with regard to reactions of the soil pH.

The treatments resulted insignificant changes in the mite populations, and in the laboratory experiments to a greater extent than in the field. Soil acidity appeared to be an essential factor to explain the changes observed, but because the two nitrogen compounds caused a similar response without relation to pH, it was concluded that nitrogen as a nutrient also plays role in regulating the mite communities in coniferous forest soil.

Résumé

Effets de fertilisation et manipulation du pH sur les populations d'acariens dans le sol de forêts de conifères

Les effets de fertilisants azotés (urée et nitrate d'ammonium) et de traitements résiduels par cendre sur les populations et les communautés des Acariens du sol de forêts de conifères ont été étudiés à l'aide de deux expériences sur le terrain et de deux autres en laboratoire.

Dans le but de séparer le rôle des substances nutritives de celui de l'acidité, le fertilisant résiduel par cendre a été contrôlé avec du $Ca(OH)_2$, comme le sol non traité. Les deux formes d'azote différaient aussi l'une de l'autre, par rapport aux réactions du pH du sol.

Les traitements se marquent en changements significatifs dans les populations d'acariens, et de manière encore plus nette dans les expériences de laboratoire que sur le terrain. L'acidité du sol semble être un facteur essentiel pour expliquer les changements observés, mais, comme les deux formes d'azote provoquent une réponse analogue sans relation avec le pH, on en conclut que l'azote, en tant que substance nutritive, joue aussi un rôle régulateur dans les communautés d'Acariens du sol des forêts de conifères.

Acknowledgements

The research was partly supported by the National Research Council for Sciences, Academy of Finland. The field experiment I was established by Kemira Oy, Helsinki. Working facilities were offered by the Department of Zoology, University of Helsinki,

Department of Biology, University of Jyväskylä and the Computer Centre, University of Jyväskylä. We wish to thank these institutions, and also to express our special thanks to our co-workers Mrs. RIITTA HYVÖNEN, M. Sc., Mr. PEKKA VILKAMAA, Lic. Phil., and Mr. PEKKA LAITAKARI. Dr. SIGMUND HÅGVAR, Norwegian Forest Research Institute, has kindly read the manuscript and given several valuable comments.

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